Entropy-based resource management:

"Smart, Smart Cities with Green, Complete Streets"

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Does your community need a sustainable land use plan? Sustainable roadway grid? Strategy for climate change? Strategy for driverless cars?

Are your commutes miserable? Air quality alert days increasing? Wetlands drying up? Summer stream flows too low?

Let's "think negative entropy" for a few minutes....

Sustainability: "Mr. Malthus – meet Mr. Smuts"

First, let's frame this sustainability discussion. Some of you might remember Thomas Malthus from high school history. Tom was a gloomy old English guy who told us we were all going to die, because our available farmland could only provide enough food for just so many people, and our population would soon reach that limit. Our food source was unsustainable, in modern terms. As I said—gloomy.

The answer, though, was that we just needed to get more efficient with our resource management. Enter Jan Smuts—a very interesting character and the only person to sign peace treaties from both the First and the Second World Wars. Not content with saving the world, Jan turned his attention to trying to save the planet, by developing the philosophy of holism ("the whole is more than the sum of its parts"). If you want your farmland to be highly productive, you would need to manage it in a holistic way; you'd pay close attention to all your operations, and,

Field Marshall Smuts: planet saver. By Yousuf Karsh, CC BY-SA 3.0 nl, https://commons.wikimedia.org/w/index.php?curid=37130597

what's more, you'd manage them all together as one big system. That way you can get more food from that same farmland acreage and so feed a bigger population: Jan Smuts's answer to Malthus's dilemma.

So, we're saying here that being holistic in our resource management might be the best way for us engineers to do our part in the quest for sustainability.

Just "be holistic," though, isn't much of a specification for an engineer. We have this geeky urge to get a better understanding of the physics behind it all. At a simple level, "mimicking natural systems", as our biologist pals often ask us to do, seems to make sense. A fuller understanding of the physics of how those natural systems work, though, might be able to help us even more.

The entropy-based resource management organizing principle

So just what does "a holistic method that mimics a natural system" mean for us engineers? The premise used here is that natural processes always act to use energy efficiently and minimize energy loss at all times, and so leave all resources in a state of minimum entropy (maximum order) after each process has been completed. By doing that, the resource is always maintained in its highest, most ordered state, at the highest energy level possible. Entropy-based resource management is basically about finding simple, effective ways to create or maintain order, to *create negative entropy*, when managing all our resources.

> Nature, using the sun's energy and following the laws of physics, creates highly efficient, low entropy systems.

Let's apply that principle to one important resource—water and the annual rainfall supply. How might we best manage that supply to maximize its availability to support everything and everybody in our watershed? Well, water in solid phase at the highest potential energy possible would be snow on the mountaintop. And we know that having a good snowpack is very helpful throughout the year. Let's drop down a phase. Water in liquid phase at the highest potential energy possible is just high groundwater, so we want that too. We really want that, as it turns out—a firm focus on establishing and maintaining high groundwater elevations throughout our watersheds is the fundamental entropy-based strategy for water resources.

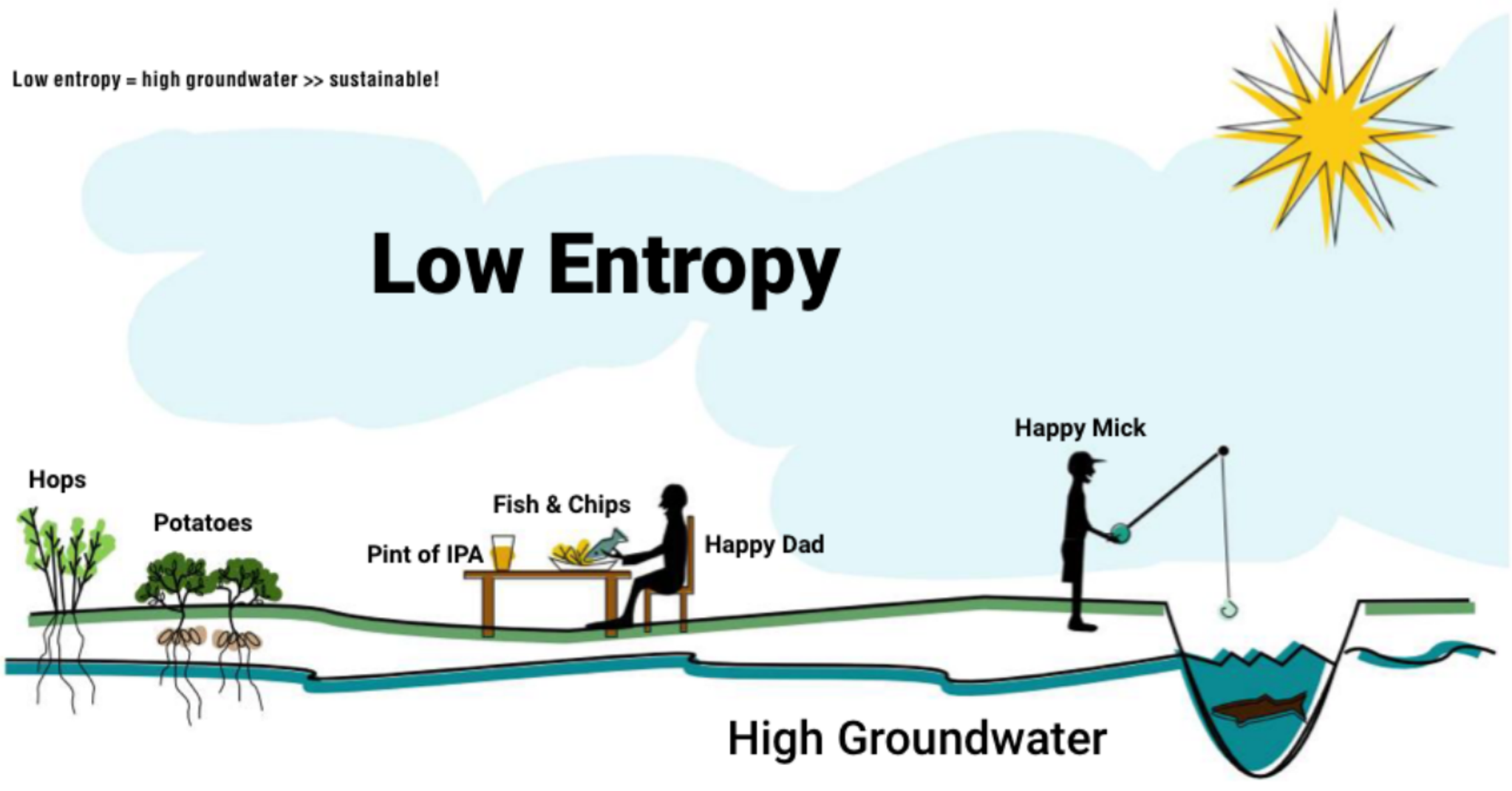
"Entropy-based resource management" is a bit of a mouthful. However, as the water example shows, it's really just the efficient storage and frugal use of all our natural resources. Using that more descriptive language can help us develop simple sustainability strategies.

The Sustainable City

Next, let's look at how use of this organizing principle might play out in a bit more detail, and see how our planning and public infrastructure design might help optimize management of our energy, water and air resources, the basic building blocks for life in "the sustainable city." Since we looked at water the last time, let's look now at energy.

As public works agencies we're not generally in the energy development/energy storage business, though we'd

Low entropy = high groundwater >> sustainable!



like folks to develop as many types of cheap energy as possible, and we also have a preference for those that don't cause us to spend money cleaning up our water and air resources. In our cities and public infrastructure, though, we're really more in the mode of being frugal in using that energy. How might we approach doing that? What practices might already be doing it? Here are some strategies and related practices that are consistent with using an entropy-based approach:

- Minimize the work that needs to be done (i.e., travel) before you can do your productive work (telecommuting; 20 Minute Neighborhoods; *Smart Growth* plan)
- Maximize choice in how best to complete that work – what energy types to use, where and when (bike lanes; *Complete Streets*; First Mile Travel options; roundabouts)
- Promote efficiencies in completing the work (design for travel time vs. maximum speed; mass transit; entropy-based traffic signalization; *Smart Infrastructure*)

So far, so good. But all that still isn't enough. Remember, we are also constrained to be holistic—to address air and water at the same time. So:

- Electric cars are favored over gas (about as energy efficient, but score better for the air resource)
- Add roadside bioretention cells to the roadway cross section (*Green Streets*, better for the water resource)

And, because we've been holistic (remember, the whole is more than the sum of its parts), we get added bonuses:

- Healthier citizens (bikes are a good workout)
- Safer roads (a roundabout benefit)
- Cleaner air (and we didn't even have to develop anything specific to get it).

So, using an entropy-based resource management approach for our sustainable city, we'd basically end up with a *Smart Growth* plan, serviced by *Smart Infrastructure* and a *Complete Streets* roadway grid made up of *Green Streets*. It would give us "Smart, Smart Cities with Green, Complete Streets." Throw in some AI, for more energy savings.

Well, we're in a bit of a pickle.....

Global warming has upped the ante a wee bit. Our communities' needs are pressing. Our engineering responses must now include less "discounted externalities" and result in fewer "unintended consequences." We've been directed to "do more with less," and so must try to achieve "more than the sum of its parts-level" efficiencies.

Nature, using the sun's energy and following the laws of physics, creates highly efficient, low entropy systems and environments for us to thrive in. We can do the same. The entropy-based resource management organizing principle acknowledges the biologists' intuition that we should mimic nature and translates it into applied physics and math, where we engineers are more comfortable and where we need to be to convince skeptical policy makers.

Public works engineers have always listened to our citizens and given them what they need to be healthy and happy. Next time your citizens are pleading with you for a sustainable economy and environment, think holistically—"think negative entropy"!

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